C-2.1 Illustrate electron configurations by using orbital notation for representative elements

Revised Taxonomy Level 2.2-B <u>Exemplify</u> (<u>illustrate</u>) conceptual knowledge

In Physical Science, Students

- ❖ Compare the subatomic particles (protons, neutrons, and electrons) on an atom with regard to mass, location, and charge, and explain how these particles affect the properties of an atom (including identity, mass, volume, and reactivity). (PS-2.1)
  - ➢ The electron cloud is the space where electrons are moving erratically in regions of space called energy levels
    - ♦ Energy levels are regions of space at increasing distances from the nucleus
    - ♦ There is a maximum number of electrons that can occupy each energy level and that number increases the further the energy level is from the nucleus

    (Students did not address quantum numbers in physical science)
- ❖ Explain the trends of the periodic table based on the elements' valence electrons and atomic numbers. (PS-2.3)
  - ➢ Determine how many energy levels are occupied in a given element by recognizing that the period in which an element appears on the periodic table indicates the number of occupied energy levels.
  - ➢ Determine the number of valence electrons for selected groups of elements (groups 1,2,13,14,15,16,17,18) when given the element's group number or name

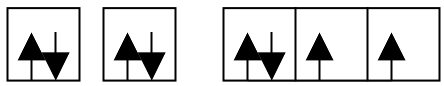
    (Students have not been introduced to electron orbital notation)

It is essential for students to

- ❖ Understand that the representative elements are those elements within the first two groups (groups I and II on the far left) and the last six groups on the right of the Periodic Table.
- ❖ Understand the first two quantum numbers and use them to describe the location of electrons in representative elements in the ground state
  - ➢ Principle quantum number
    - ♦ Understand the aspect of electron location described by the principle quantum number. (Energy level)
    - ♦ Understand that the principle quantum number is designated by numbers 1 through 6 and understand the meaning of each of those numbers in reference to the location of the electron.
  - ➢ Orbital quantum number
    - ♦ Understand the aspect of electron location described by the orbital quantum number. (Type of orbital)
    - ♦ Understand that the orbital quantum number is designated by one of four letters (s,p,d,f) and understand the meaning of each of those letters in reference to the location of the electron
    - ♦ Understand how many of each type of orbital are possible in each of the 6 energy levels.
    - ♦ Understand that two electrons can occupy each orbital

- Use standard orbital notation to illustrate the electron configuration of a representative element in the first three periods based on the element's position on the periodic table.

Orbital Notation for Oxygen:



1s 2s 2p

  - Additional methods of illustrating electron configuration include
    - Electron configuration notation

      For oxygen: $1s^2 2s^2 2p^4$

    - Electron Dot notation (to show valence electrons)

      Electron Dot Notation or Selenium:

Tradition Chemistry differentiation

- Understand the last two quantum numbers and use them to describe the location of electrons in representative elements in the ground state
  - Magnetic quantum number
    - Understand what aspect of electron location this describes.
    - Understand that it is designated by one of 7 numbers and understand what each of those numbers mean in reference to the location of the electron.
  - Spin quantum number
    - Understand what aspect of electron location this describes.
    - Understand that it is designated by numbers a positive (+) or a negative (-)
    - Understand that two electrons occupying the same orbital must have opposite spins
  - Understand that no two electrons in an atom can the same set of quantum numbers
- Illustrate the electron configuration for all elements on the periodic table,
  - Understand that the order in which electrons fill orbitals reflect the most stable electron arrangement for the given number of electrons.
    - Students should be able to make general statements concerning stable electron arrangements
      - All "d" orbitals are less stable than the "s" orbitals in the next-highest energy level
      - All "f" orbitals are less stable than the "s" and the "p" orbitals which are two energy levels higher, and less stable than the "d" orbitals which are one energy level higher
- Understand exceptions to the normal orbital filling order (Cr, Mo, Cu, Ag, Au)
  - What the exceptions are
  - Why they are exceptions
- Use a Bohr model of the atom to explain the bright line spectrum in terms of electrons moving between energy levels

Assessment
The verb exemplify (illustrate) means to find a specific example or illustration of a concept or principle, therefore the major focus of assessment will be for students to give examples that show that they understand stable electron arrangement of representative elements in the ground state. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand the characteristics of the quantum numbers and can use those characteristics to predict the stable electron arrangement of elements. Because students must demonstrate conceptual knowledge, assessments should require that students justify why their examples meet the above criteria.

C-2.2 Summarize atomic properties (including electron configuration, ionization energy, electron affinity, atomic size, and ionic size).

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

In Physical Science students

- ❖ Predict the charge that a representative element will acquire according to the arrangement of electrons in its outer energy level.(PS-2.5)

It is essential for all students to

- ❖ Understand the following atomic characteristics and properties (in terms of atomic structure) and understand what variables influence the magnitude of the characteristics or properties for a given element.
  - ➢ Electron configuration
  - ➢ Ionization energy
  - ➢ Electron Affinity
  - ➢ Relative size of atoms
  - ➢ Ionic size

Tradition Chemistry differentiation

- ❖ Understand electronegativity

Assessment

The revised taxonomy verb, summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students have a deep conceptual understanding (in terms of atomic structure) of the terms electron configuration, ionization energy, electron affinity, and atomic radius, and ionic radius. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand how atomic structure determines the characteristics and also how the characteristics influence each other, (for example, how atomic size influences reactivity).

C-2.3 Summarize the periodic table's property trends (including electron configuration, ionization energy, electron affinity, atomic size, ionic size, and reactivity).

Revised Taxonomy Level 2.4 Summarize conceptual knowledge

In Physical Science students

- Become familiar with the periodic table in terms of
  - Locating periods and groups
  - Locating metals, metalloids, and nonmetals
  - Locating and listing referenced elements when prompted with a period number or group number
  - Determining a given element's atomic number.
  - Determining the number of electrons that an atom of a given element contains.
  - Determining how many energy levels are occupied in a given element by recognizing that the period in which an element appears on the table indicates the number of occupied energy levels.
  - Determining the number of valence electrons.
- Explain the trends of the periodic table based on the elements' valence electrons (PS-2.3)
  - Valence electrons across a period. (1-3 only)
  - Valence electrons top to bottom within a group.
  - Energy levels across a period.
  - Energy levels from top to bottom within a group.

It is essential for all students to

- Identify the chemical and physical properties off elements according to their location on the periodic table.
- Understand the structure of the periodic table and be able to explain the properties on which it is based and its unique shape..
- Understand how the value of atomic characteristics and property trends vary from element to element across and from top to bottom on the periodic table
  - Including
    - Electron configuration
    - Ionization energy
    - Electron Affinity
    - Atomic radius
    - Ionic radius
    - Reactivity
  - Be able to describe each trend in terms of how the value changes across a given period and from top to bottom in a given group.
  - Understand why the trend occurs (according to atomic structure and periodic table arrangement).
  - Be able to predict relative values (greater or smaller) for each of the characteristics or properties for a given set of elements based on their positions on the periodic table.

Tradition Chemistry differentiation

- Understand the trend of electronegativity values on the periodic table

Assessment
The revised taxonomy verb, summarize means “to abstract a general theme or major point” For this indicator, the major focus of assessment should be to insure that students have a conceptual understanding of how the periodic table is arranged so that it can be used to infer the characteristics and properties of elements. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case students understand how the periodic table is used as a tool for chemistry

C-2.4 Compare the nuclear reactions of fission and fusion to chemical reactions (including the parts of the atom involved and the relative amounts of energy released).

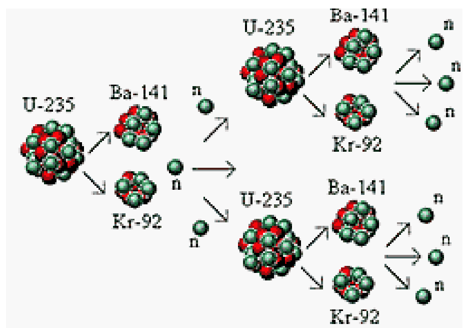
Revised Taxonomy Level 2.6 <u>Compare</u> conceptual knowledge

In Physical Science students:

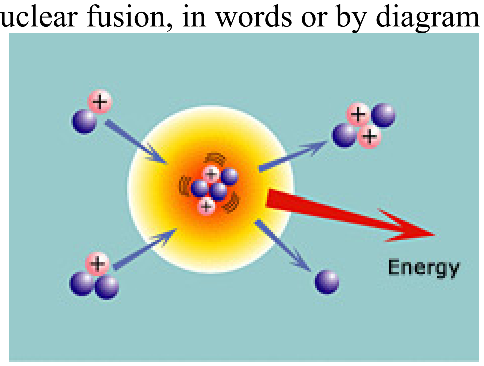
- ❖ Compare fission to fusion (including the basic processes and the fact that both fission and fusion convert a fraction of the mass of interacting particles into energy and release a great amount of energy. (PS-2.6)

It is essential for the students to

- ❖ Understand that chemical reactions occur in the electron clouds of atoms and nuclear reactions involve the nuclei of atoms.
- ❖ Illustrate the process of nuclear fission either in words or with a diagram



- ❖ Understand that there are several possible reactions that may occur during a fission reaction.
- ❖ Illustrate the process of nuclear fusion, in words or by diagram



- ❖ Understand that there are many possible reactions that may occur during a fusion reaction.
- ❖ Understand the source of energy from a nuclear reaction in terms of the nuclear mass equivalent, (mass defect) and Einstein's equation, $E = mc^2$
  - ➢ For energy release in fusion or fission, the products need to have a higher binding energy per nucleon (proton or neutron) than the reactants.
- ❖ Understand that the energy that results from a chemical reaction is the energy associated with chemical bonds (involving the electrons of the atom).
- ❖ Differentiate the energy from fusion reactions, fission reactions, and chemical reactions in terms of
  - ➢ Fuel

- Reaction Temperature
- Energy released per kg of fuel
- Energy-Releasing Reactions
- Region of the atom involved in the reaction

	Chemical	Fission	Fusion
Sample Reaction	$C + O_2 \rightarrow CO_2$	n + U-235 -> Ba-143 + Kr-91 + 2 n	H-2 + H-3 -> He-4 + n
Typical Inputs (to Power Plant) (Fuel)	Bituminous Coal	UO_2 (3% U-235 + 97% U-238)	Deuterium & Lithium
Typical Reaction Temperature (K)	700 K	1000 K	10^8 K
Energy Released per kg of Fuel (J/kg)	3.3×10^7 J/kg	2.1×10^{12} J/kg	3.4×10^{14} J/kg

Traditional Chemistry Differentiation

- Write and balance equations for a fission reactions (for example)
  - $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{142}_{56}Ba + ^{91}_{36}Kr + 3\,^{1}_{0}n$
  - $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$
  - $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{137}_{52}Te + ^{97}_{40}Zr + 2\,^{1}_{0}n$
  - Etc.
- Write and balance equations for a fusion reactions (for example)
  - $2\,^{1}_{1}H \rightarrow ^{2}_{1}H + ^{0}_{-1}e$
  - $^{1}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + \gamma$
  - $2\,^{2}_{1}H \rightarrow ^{3}_{1}H + ^{1}_{1}H$
  - $2\,^{3}_{2}He \rightarrow ^{4}_{2}He + 2\,^{1}_{1}H$
  - Etc.

Assessment

As stated in the indicator, the major focus of assessment is to compare (detect correspondences) in the nuclear reactions of fission and fusion to chemical reactions. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand the processes in terms of the differences in the parts of the atom involved and the relative energy released.

C-2.5 Compare alpha, beta, and gamma radiation in terms of mass, charge, penetrating power, and the release of these particles from the nucleus.

Revised Taxonomy Level 2.6 <u>Compare</u> conceptual knowledge

This concept was not addressed in physical Science

It is essential for students to

- ❖ Understand the type of radiation that may be emitted during nuclear reactions

Type of radiation emitted & symbol	Nature of the radiation	Nuclear Symbol	Penetrating power, and what will block it	Effect of release of particles from the nucleus
α Alpha	a helium nucleus of 2 protons and 2 neutrons, mass = 4, charge = +2	${}^{4}_{2}He$	Low penetration stopped by a few cm of air or thin sheet of paper	Reduces the atomic mass number by 4 Reduces the atomic number by 2
β Beta	high kinetic energy electrons, mass = 1/1850 of alpha, charge = -1	${}^{0}_{-1}e$	Moderate penetration, most stopped by a few mm of metals like aluminum	Is the result of neutron decay and will increase the atomic number by 1 but will not change the mass number
γ Gamma	very high frequency electromagnetic radiation, mass = 0, charge = 0	${}^{0}_{0}\gamma$	Very highly penetrating, most stopped by a thick layer of steel or concrete, but even a few cm of dense lead doesn't stop all of it!	Is electromagnetic radiation released from an excited nucleus. The atomic number and mass number do not change.

Assessment

As stated in the indicator, the major focus of assessment is to <u>compare</u> (detect correspondences) in the most common types of radiation that are released during nuclear reactions. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand how the structure of the particle determines its penetrating effect and ionization power.

C-2.6 Explain the concept of half-life, its use in determining the age of materials, and its significance to nuclear waste disposal.

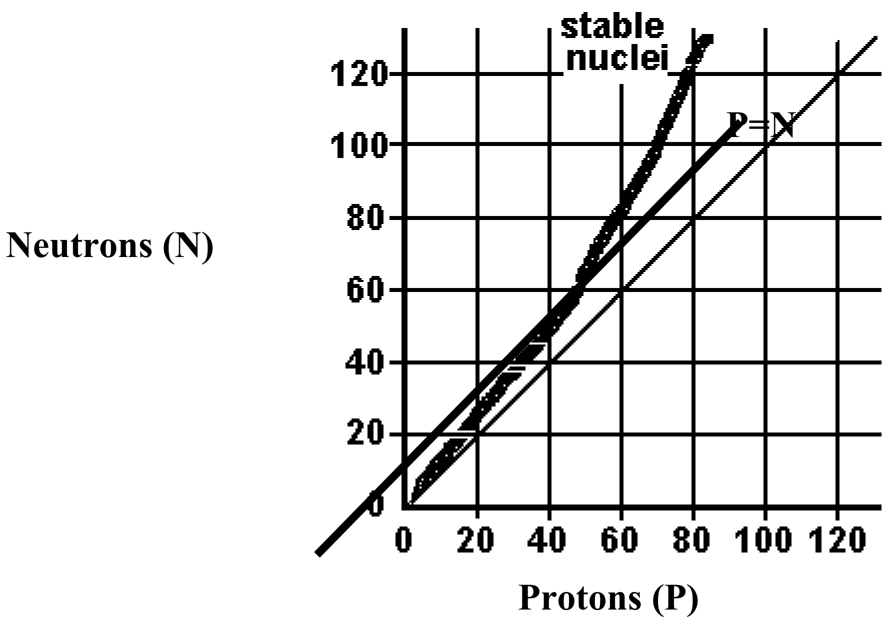
Revised Taxonomy Levels 2.7 B <u>Explain</u> conceptual knowledge

Key concepts

This topic was not addressed in physical science

It is essential for students to

❖ Understand that only certain combinations of protons and neutrons seem to be stable (see <u>stability curve</u> graph). Any isotope of any element that does not lie in the stability band with a stable neutron/proton ratio is likely to be radioactive.



- ➢ There are no stable nuclei with an atomic number higher than 83 or a neutron number higher than 126.
- ➢ The more protons in the nuclei, the more neutrons are needed for stability.
  - ♦ The stability band pulls away from the P=N line.
- ➢ Stability is favored by even numbers of protons and even numbers of neutrons.

❖ Understand that radioactivity results from the random and spontaneous breakdown of the unstable nucleus of an atom. This breakdown is called radioactive decay of the unstable atom/nucleus/radioisotope.
- ➢ In the breakdown of the unstable nucleus, energy is released by the emission of alpha, beta and gamma ionizing radiation.
- ➢ The breakdown of an unstable atom is referred to as decay or disintegration and is a random process meaning it is a matter of chance which particular nucleus decays.

❖ Understand that not all of the atoms of a radioisotope decay at the same time, but they decay at a rate that is characteristic to the isotope. The rate of decay is a fixed rate called a half-life.
- ➢ The half-life of a radioisotope describes how long it takes for half of the atoms in a given mass to decay.

  - Some isotopes decay very rapidly and, therefore, have a high specific activity. Others decay at a much slower rate.
- Understand carbon dating
  - As soon as a living organism dies, it stops taking in new carbon.
  - The ratio of carbon-12 to carbon-14 at the moment of death is the same as every other living thing, but the carbon-14 decays and is not replaced.
  - The carbon-14 decays with its half-life of 5,700 years, while the amount of carbon-12 remains constant in the sample.
  - By looking at the ratio of carbon-12 to carbon-14 in the sample and comparing it to the ratio in a living organism, it is possible to determine the age of a formerly living thing fairly precisely.
- Understand how the half life of nuclear waste determines how it is processed and stored.

Assessment

The verb, explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how the half life of a radioactive element determines its effect on the environment. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how the nuclear structure of the atom determines its stability, and the process and consequences of the decay of unstable elements.

The following three indicators (2.7 – 2.9) should be selected as appropriate to a particular course for additional content and depth:

C-2.7 Apply the predictable rate of nuclear decay (half-life) to determine the age of materials.

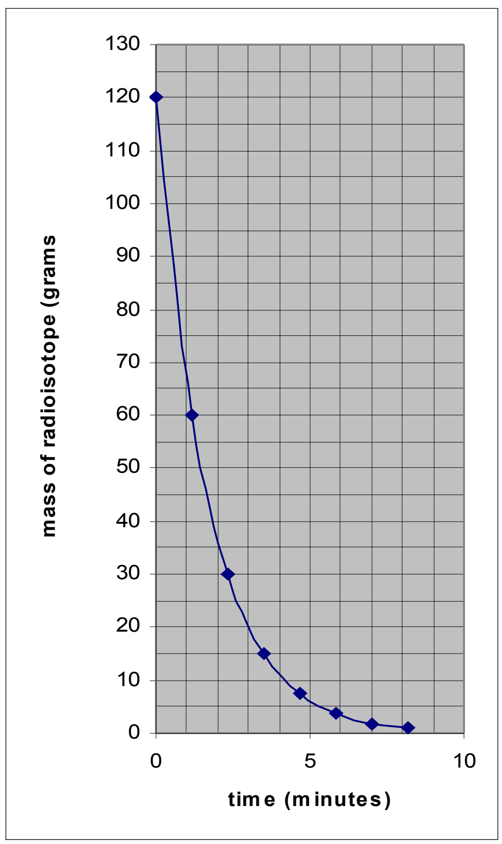
Revised Taxonomy Level 3.2 C_A <u>Apply</u> (<u>use</u>) procedural knowledge
Students did not address this concept in physical science

It is essential for students to

- Determine the half life of a substance when given the change in the mass of the radioisotope over time. (for example)
  - Given:
    - The initial mass of Protoactinium-23 is120 g
    - The final mass is 1.88 g
    - The elapsed time is 7 minutes
  - The sequence for decays would be:
    - 120g>60g>30g>15g>7.5g>3.75g>1.88g
    - This is 6 half lives.
  - So one half life is
    - 7 minutes / 6 = 1.17 minutes.
- Interpolate the age of a substance at a given time using a graph of mass vs time
  - Make a chart by adding 1.17 minutes (the calculated half life) for successive time periods and dividing the mass in half for each successive time period.

Mass (grams)	Time (minutes)
120	0
60	1.17
30	2.34
15	3.51
7.5	4.68
3.75	5.85
1.875	6.92

    - Graph the data



Rate Laws are beyond the scope of most introductory chemistry courses

Assessment

The revised taxonomy verb for this indicator is implement (use), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for determining the half-life of a substance from laboratory data and the use of that data to determine the age of a given specimen. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of the decay of radioactive isotopes

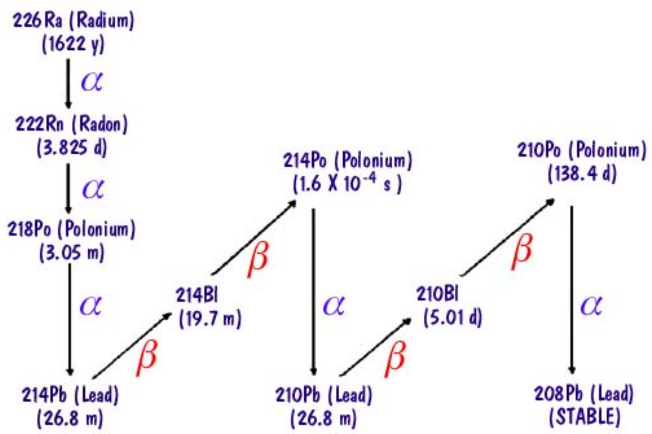
C-2.8 Analyze a decay series chart to determine the products of successive nuclear reactions and write nuclear equations for disintegration of specified nuclides

Revised Taxonomy Level 4 **<u>Analyze</u> conceptual knowledge**

Students did not address this concept in physical science

It is essential for students to

- Interpret a radioactive decay series such as the one below



Radium-226 (Uranium-238) decay series with half-lives.

- Write and balance nuclear equations for each of the steps in a decay series
  - ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rd + {}^{4}_{2}He$
  - ${}^{222}_{86}Rd \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$
  - ${}^{218}_{84}Po \rightarrow {}^{214}_{82}Pb + {}^{4}_{2}He$
  - ${}^{214}_{82}Pb \rightarrow {}^{214}_{83}Bi + {}^{0}_{-1}e$
  - Etc.

Assessment

The revised taxonomy verb for this indicator is analyze which means to "break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose". In this case, students should be able to look at the decay series diagram and determine the particles which are produced by each successive step. Because the indicator is written as <u>conceptual knowledge,</u> assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand the reasons for the values of mass number and atomic number for each of the substances and particles.